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Investigation on Performance of Bacterial Concrete Amended by Metakaolin as Supplementary Cementitious Material

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Abstract - *A typical durability related problem in many concrete constructions is crack formation. While larger crack disturbs the structural integrity, smaller micro cracks may result in creating durability problems. Chemicals which are harmful causes premature degradation of matrix along with corrosion of embedded steel. As regular maintenance and repair of concrete structures are costly affairs, introduction of self-healing repair mechanism proves high beneficial as it reduces maintenance cost and increase durability of structures. Concrete shows some self-healing property i.e the ability to heal or seal freshly formed micro cracks. This characteristic is mainly because of presence of non-hydrated excess cement particles in the matrix, which undergo delayed or secondary hydration upon reaction with ingress water. In this experimental investigation a concrete partially replacing cement with Metakaolin and having self-healing property is developed. A concrete having cement partially replaced by 10%, 15%, 20 % of metakaolin with addition of bacterial solution of 5 %, 10 %, 15%, 20% along with all the key ingredient is prepared and tested. This research focuses on producing high strength concrete by investigating on the strength parameters and self-healing property of bio-concrete and the best combination having optimum dosage of bacterial solution and optimum amount of metakaolin for production high strength concrete is suggested.*

***Key Words*: Bacillus Bacteria, Self-Healing Concrete, Metakaolin, Rapid Chloride Penetration test, Ultra Sonic Pulse velocity test.**

1. INTRODUCTION

Main ingredients of concrete contain cement, aggregates, water and admixtures (whenever necessary). Production of cement has a very severe impact on environment due to the carbon dioxide (CO_2) emission [22]. Along with energy consumption for production and transportations, several other problems like air pollutions, impacts on landscape etc are also matter of concern. A need to increase service life of concrete structure by not only using good material but also by sustainable material is generated. Concrete structures are susceptible to cracking which allows water and damaging chemicals to enter and degrade the concrete, reducing the durability of structure as well as requiring costly maintenance and repairs. Formation of cracks cannot be avoided. Cracks which are bigger in size damages structures integrity and it require repairs actions while smaller size cracks having crack width smaller than 0.2 mm are considered problematic [11-12]. Such micro cracks do not affect the strength properties of structures but on the other hand makes the structure porous and permeable providing path for ingression of environment moisture. Harmful chemicals like chlorides, sulphates and acids results in degradation of concrete matrix along with premature corrosion of steel reinforcement, damaging structures durability thus reducing its life span. To overcome this issue use of suitable bacteria as a healing agent was explored. In this spore of specific alkaline resistant bacteria of genus bacillus were added to the concrete mix as a self-healing agent. These spores after activation produce copious amount of crack filling calcium carbonates-based minerals which heals the cracks [8]. In this experimental investigation, the effects of adding bacteria into the concrete mixture with partial replacement of cement with metakaolin is carried out. The results are analyzed and the optimum dosage of bacterial solution and metakaolin is suggested.

2. METHODOLOGY

The main reasons for failure of the structure are cracks. In present experimental research work, an alternative self-repair method to arrest the cracks by using bacteria is adopted. To achieve the objectives of the research the following tasks are performed:

1. The materials are collected from a specific location and properties are studied.
2. Prepare the design mix of M60 grade by using bacterial solution (5 %, 10 %, 15 %, 20 %) with partially replacement of cement by (10 %, 15 %, 20 %) of Metakaolin.
3. Cubes are casted and compressive strength test; ultra-sonic pulse velocity test and Rapid chloride penetration test were performed on 7, 28 and 56 days.
4. Results were analysis and conclusion are drawn.

2.1 MATERIALS

The materials used for this experimental investigation are:

1. Cement (IS: 269:2015)
2. Metakaolin (MK) (IS: 16354)
3. Fine aggregate (C. Sand) (IS: 383:2016)
4. Coarse aggregate (CA I & CA II) (IS: 383:2016)
5. Water (IS 456:2000)
6. Bacterial solution (BS)

3. RESULTS AND ANALYSIS

3.1 Compressive Strength Test Results

Compressive strength tests were performed on the cube specimens at the ages of 7, 28 and 56 days. The compressive strength results obtained for partial replacement of cement by Metakaolin (10%, 15% and 20%) and bacterial solution (5%, 10%, 15% and 20%) are shown below.

From figure 1. gives the clear image of the variation in the compressive strength test. It indicates that the concrete prepared by 20 % of Bacterial Solution and 10 % of Metakaolin gives the better result as compared to other bacterial solution.

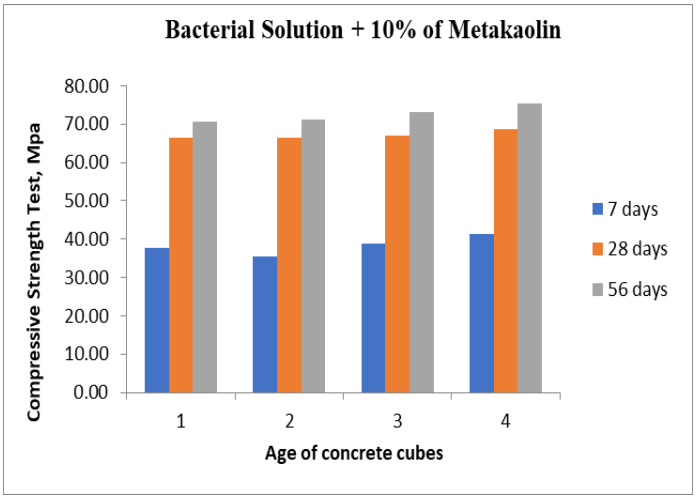

Figure 1: Compressive Strength Test Result

Figure 2. indicates the test results obtained from compressive strength test. The concrete prepared by 20 % of Bacterial Solution and 15 % of Metakaolin gives the better result as compared to other bacterial solution.

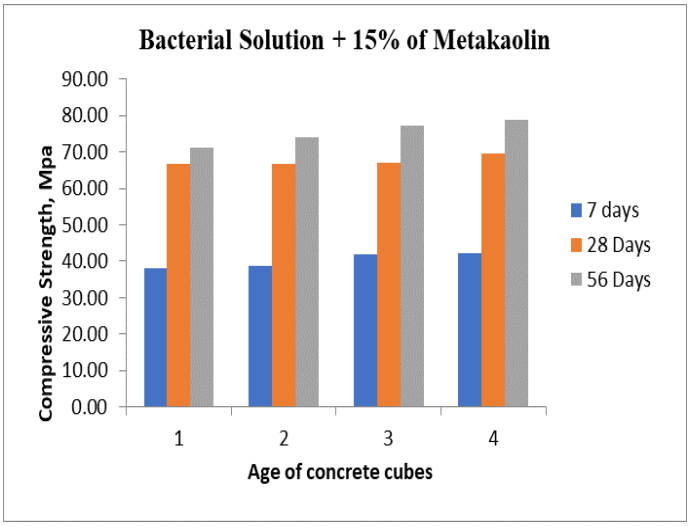

Figure 2: Compressive Strength Test Result

Figure 3. indicates the test results obtained from compressive strength test. The concrete prepared by 20 % of Bacterial Solution and 20 % of Metakaolin gives the better result as compared to other bacterial solution

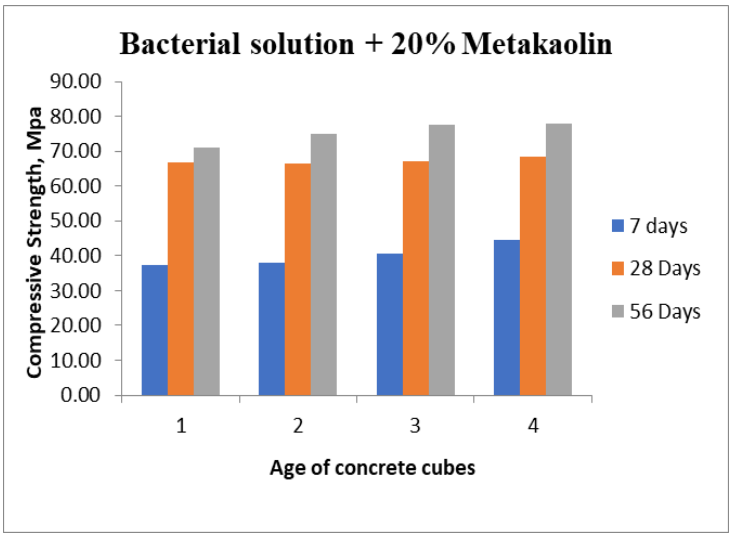

Figure 3: Compressive Strength Test Result

Variation in compressive strength shows the rise in compression strength, all the three proportions are giving encouraging results when tested for compressive strength.

3.2 Ultrasonic Pulse Velocity Results

For each concrete mix, UPV test was conducted on cubes specimens for 28, and 56 days.. The results obtained from the tests on the binary mixes made from blending cement concrete with different MK and BS proportions are evaluated and discussed below.

Figure 4. indicates the test results obtained from UPV test. The concrete prepared by 20 % of Bacterial Solution and 10

% of Metakaolin gives the better result as compared to other bacterial solution.

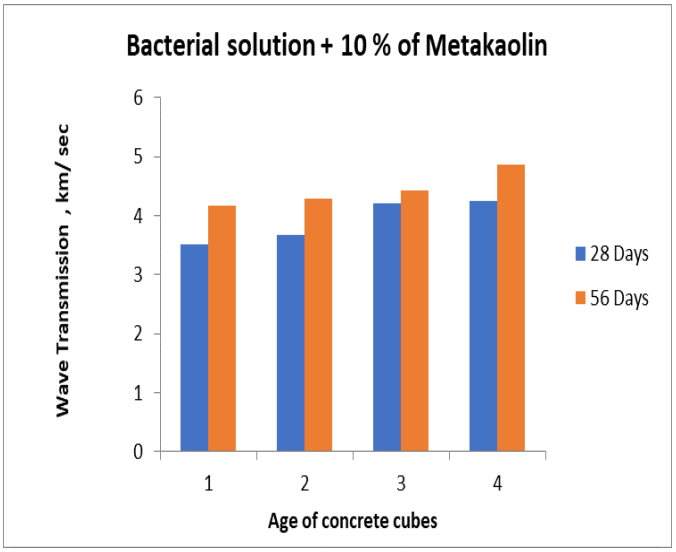

Figure 4: UPV Test Results

Figure 5 indicates the test results obtained from UPV test. The concrete prepared by 20 % of Bacterial Solution and 15 % of Metakaolin gives the better result as compared to other bacterial solution.

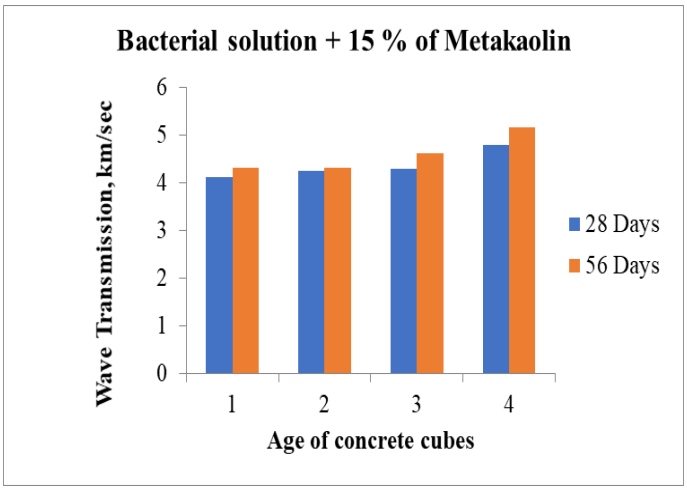

Figure 5: UPV Test Results

From figure 6 shows the test results obtained from UPV test. The concrete prepared by 20 % of Bacterial Solution and 20% of Metakaolin gives the better result as compared to other bacterial solution.

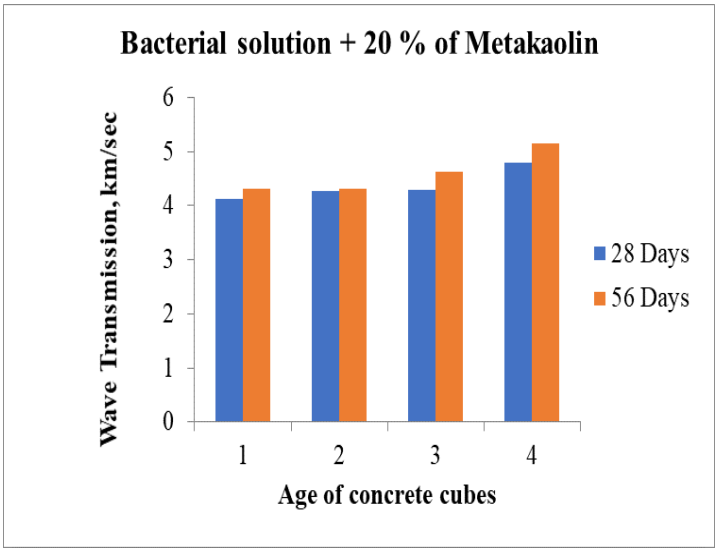

Figure 6: UPV Test Results

After analyzing the results, it can be concluded that the concrete mix prepared by partially replacing cement by 15% and having bacterial solution 20% gives best result as compared to other proportions.

3.3 Rapid Chloride Penetration Test Result

The results of the rapid chloride permeability test are given below:

Figure 7 shows the test results obtained from RCP test. The concrete prepared by 20 % of Bacterial Solution and 10 % of Metakaolin gives the better result as compared to other bacterial solution.

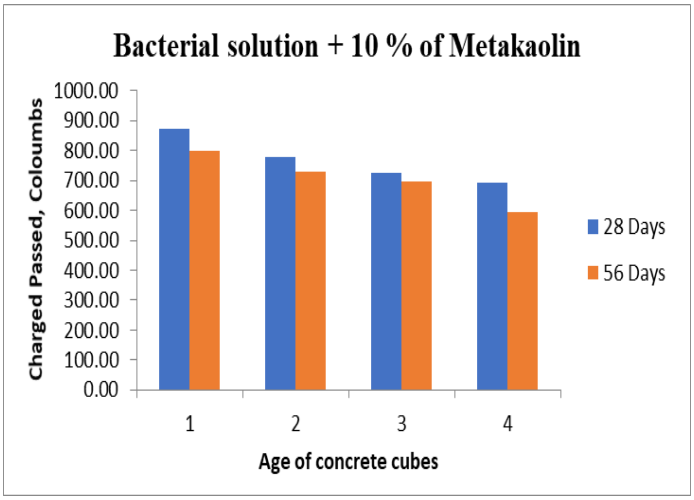

Figure 7: RCP Test Results

Figure 8 shows the test results obtained from RCP test. The concrete prepared by 20 % of Bacterial Solution and 15 % of Metakaolin gives the better result as compared to other bacterial solution.

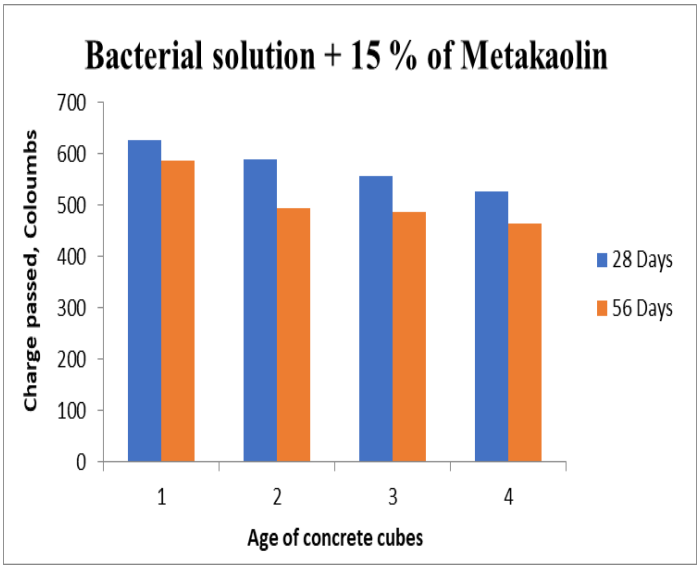

Figure 8: RCP Test Results

Figure 9 shows the test results obtained from RCP test. The concrete prepared by 20 % of Bacterial Solution and 20 % of Metakaolin gives the better result as compared to other bacterial solution.

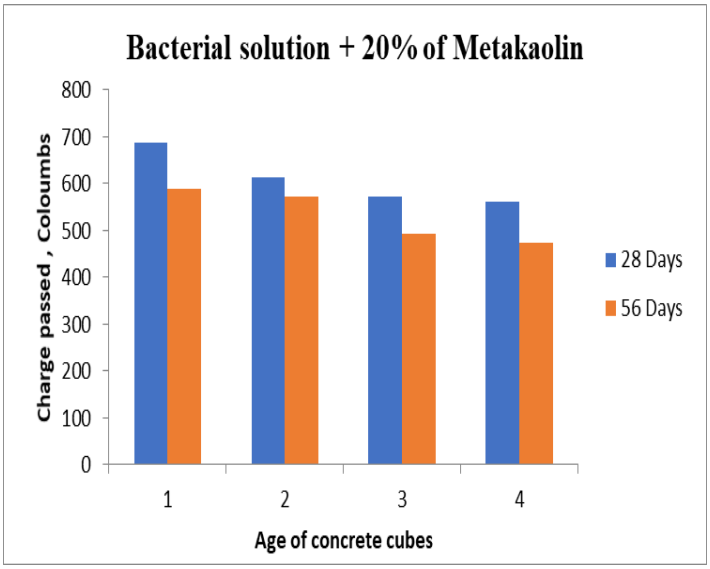

Figure 9: RCP Test Results

The concrete with 15% MK and 20% BS replacement showed the best performance when compared to the other proportions.

4. SUMMARY

1. The use of bacterial solution and metakaolin are giving encouraging results.
2. From compressive strength test it can be concluded that 20 % bacterial solution proves to be optimal dosage. From all the proportions 20 % of bacterial solution with all the percentage of metakaolin gives the desired results.
3. UPV values for mixes containing 15 % Metakaolin and 20 % of bacterial solution gives best results as compared to the other proportions. After analysing, it can be concluded that the density of concrete is increased, as the wavelength are travelling at 4.79 km/sec & 5.16 km/sec at 28 days and 56 days respectively.
   As per the UPV test chart the concrete prepared by15 % Metakaolin and 20 % of bacterial solution proportions gives concrete of excellent density.
4. Rapid Chloride Penetration test results indicates that the concrete mix prepared by partial replacement of cement by 15 % of metakaolin and 20% of bacterial solution gives the best results as compared to other proportions. The charged passed for this mix at 28 days and 56 days is 527.7 C and 465.7 C respectively, indicates the best resistance to chloride penetration as compared to the other proportions.

5. CONCLUSION

After experimental investigation of trials, and comparing all the parameters and analysing the test results it is concluded that mix prepared by partial replacement of cement by 15 % of Metakaolin with 20 % of bacterial solution proves to be the optimum proportion when compared with other proportions.

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